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SHUTTLE-DERIVED LAUNCH VEHICLES LIFE CYCLE COST ANALYSIS OF

EXECUTIVE SUMMARY

= VOLUME **DRD MA-857T**

PREPARED BY

ECON INCORPORATED

FOR

NASA/JOHNSON SPACE CENTER

NAS9-16410 ON CONTRACT

SEPTEMBER 1982

03310 noctas C2CT 55B C3/16

Se P HC A03/MP A01 San Jose, Calif.) DE SHUTTLE-DERIVED LADNCH VEHICLES. VOLUM TIPE CYCLE COST ANALKSIS (NY2Y-C8-111622)

883-2288

ABSTRACT

This study, "Life Cycle Cost Analysis of Shuttie-Derived Launch Vehicles", was performed under Contract NAS9-16410 for the Lyndon B. Johnson Space Center (JSC) of the National Aeronautics and Space Administration (NASA).

was performed using only the design, performance and programmatic definition of the Shuttle-Derived Launch Vehicle (SDLV) concepts as estabilshed by Martin Marietta and Rockwell International, the development, production and operations costs. This assessment two contractors performing SDLV conceptual studies under separate ECON, inc. conducted an independent assessment of contract to NASA.

mix of Shuttle and SDLV vehicles. These results were tested ECON also evaluated the relative life cycle costs of space transportation systems using the Shuttle alone in comparison to a against a range of mission activity levels. The final objective of this study was the calculation and comparison of the costs for alternative SDLV concepts. All costs were estimated in constant 1982 dollars.

The Final Report summarizes the results of all study efforts associated with ECON's independent assessment of life cycle costs SDLV concepts. It is structured in two volumes; Volume I, Technical Report and Volume II, the Executive Summary. for SDLV concepts.



BACKGROUND

SCOPE OF STUDY

- TWELVE MONTHS
- \$50,000,00

OBJECTIVES

- COMPARE LCC OF SDLV/SHUTTLE MIX WITH SHUTTLE ONLY
- EVALUATE LCC DIFFERENCE BETWEEN SDLV CONCEPTS
- TEST SENSITIVITY TO MISSION SCENARIO

DIFFERENCES FROM MIDTERM REPORT

- IMPROVED SYSTEM DEFINITION
- SOFTWARE COSTS PER PRICE 'S'
- POP 81-2 AND INDEPENDENTLY-EVALUATED STS COSTS
- P/A MODULE FLEET SIZED FOR UNCERTAINTIES
- MISSION MODEL TREATED PARAMETRICALLY



GROUNDRULES

1982 CONSTANT DOLLARS

TYPICAL FEE LEVELS

SHUTTLE ACQUISITION COSTS CONSIDERED SUNK

ALL DEVELOPMENT COSTS

PRODUCTION OF FOUR ORBITERS PLUS INITIAL SPARES

SDLV ACQUISITION COSTS AMORTIZED

ALL DEVELOPMENT COSTS

PROPULSION/AVIONICS MODULE FLEET ACQUISITION

SDLV DEVELOPMENT PROGRAM

ONE COMPLETE FLIGHT VEHICLE

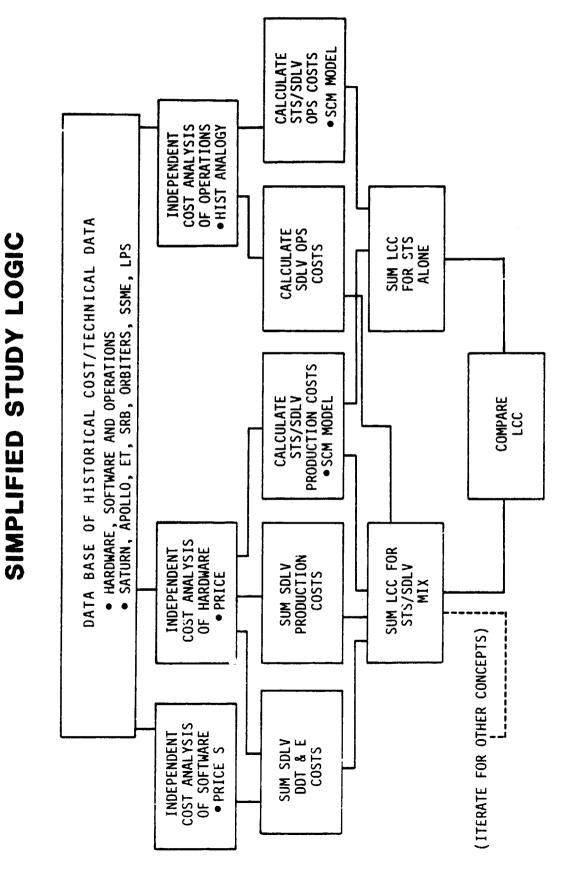
ONE TEST FLIGHT

COMMON STS/SDLV HARDWARE & OPERATIONS COSTS SHARED

CUMULATIVE AVERAGE COSTS, 1983-2000

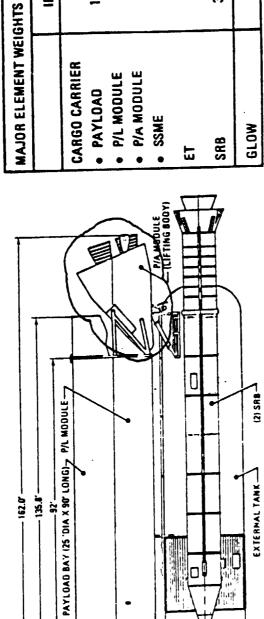
AVERAGED OVER TOTAL FLIGHT QUANTITY





- JSC INSTITUTIONAL A CS COSTS 1.9.3.2 A CS CRS1114111644 ASA JSC HORT & SUPPRE tass in state a surrent. 1.9.2 CS COSTS 1.9.2.2 - NEVE PRESENT NEW HALV PRINE CONTACTOR - NG CONTRACT ABOUT mentalities life . JC PROCESS FOR SEAVEST HOST & ORIGINAL PASSE IS OF POOR QUALITY TUTTONE STR 18511-- MCC OPERATIONS 1.0.3.1 LIGHT OFFINITIONS 1.0.3 METABOR INSTITUTIONAL COSTS 1.0.3.3 NICOVERY SITE OPERATIONS 3.8.4 . RECOVERY OPTIMATIONS 1.8.4.1 METADOR OFFICIORS 1.6.3.2 Systatutes (mass. 1.8.2.2 FLIGHT OFS. SERVICES 1.8.2 | PER. COMING. 5/9 | 1.6.1.1 F. 1947 PLANING 1.6.2.1 SECTION OF CALIFORNIA SECTIONS CS COSIS 1.7.4.3 AURCH FACILITIES 1.7.3 CONT. CONT. S. N. 1.7.2.1 FACILITIES 1.7.3.1 - PROPELLANTS 1.7.5.1 NAME IN SITE OFS 1.7.5 NUMBER SOFTWARE 1.7.2 CHECKONI/NAMINISHES FOURTHERT 1.7.1.2 NUMERI NAMBAMBE 1.7.1 - STS FACILITY MOBIL LAURCH OPERATIONS 1.7.5.2 _ VAFE PROCEAM NOM 1.7.4.1 AFB SERVICES 1.7.4 BASE INTUITIBANCE 1.7.5.5 CHCHC. 1.7.4.2 1.7.5.3 1846SP061A110H VAFB LABOUR BEGGGENT 7. BREAKDOWN STRUCTURE KSC SUSTAINING ENGING. 1.6.4.8 KSC 18511701100AL & CS CBSTS 1.6.4.3 - PROPEREMENTS 1.6.5.1 AMICH FACILITIES 1.6.3 SALV MEDICATED FACILITIES 1.6.3.1 SIS FACILITY HOOIF. 1.6.3.2 ALBICH SETE OPS 1.6.5 CONTRACTOR 1.6.1.1 ALENCH SOFTWARE 1.6.4 1.6.5.2 DASE PAINTENANCE 1.6.5.5 ALPICH INACOUNTE 1 6.1 15C PROGRAM HOPE 1.6.4.1 L 155 5/21 16.2.1 LAMICH SUPPORT 18485PORTATION 1.6.5.6 SC SERVICES 1.6.4 RDC LABREH DEGMENT -STSTEM DESTRUCTION OF THE PARTY OF THE PATIONS (NICOMISON 1100) STRUCTURES 1.1.1.2 THE STATE 1.4.1.3 P./H SERVICES 1.4.2 _ IntEG/ASSY/TUST 1.4.1.1 1.4.1 HARDIANE 1.4.1 ENCAG 1.4.2.1 ACS PROPULSION 1,4,1,4 PATIDAD MODULE DECHECHT **¥ORK** P/A MODIAE SYSTEMS MANY/FINGUE, 1.3.3.1 1.3.1.4 PROPULSION SYSTEMS 1,3,1,5 HYDRAR IC CONTROLS 1.3.1.6 POLEN BISTAIGHTION STAUCTURES 1.3.1.2 DATA MORT 1.3.1.0 FORE SERENTION 1.3.1.30 MOPUL BIOL: / AVIONES MODUL E SEGMENT THE BINE 1.3.1.3 P/A SERVICES 1.3.3 _ INTEG/ASSY/TEST P/A SOFTMANE 1.1.2 P/A HANDUAME 1.3.1 GUID. 4 MM. PJA NEFUNDEUNENE OFFRATIONS 1.3.4 SS 1,3,1,12 AVIONICS S/W 1160 1.3.1.9 (HGINE 5/W 1.2.1.2 LIGHE PROPULSION SERVICES 1.2.2 11 HARDIANE 1.2.2 -1.4608 1.2.1.1 .. - san (101060) 1.1.4.1 - san sanussi (0581) 1.1.4.2 - PROJECT (MS1) 1.1.4.3 - Sem (Philosop) 1.1.3 t - SIN SURASSY (USB1) 1.1.3.2 - EIPENBABLE 1.1.2.2 - ERPERDAGE 1.1.1.2 - RESSALE 1.1.1.1 END SUBASSY HANDHAM (USA) 1.1.2 - MENSARE 1.1.2.1 BOLIS PROPULSION SCOMENT SAN MENUSISMENT PRINTIONS 1.1.3 (Twicker, 1.1.1 SERVICES 1.1.4





PAYLOAD SHROUD-

4

289,397

₩07

INERT

2,514,420

300,420

1,642,295

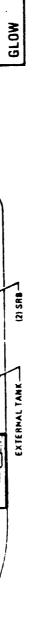
70,990

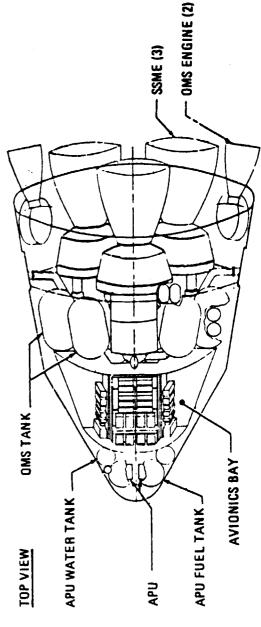
20,976

47,555 45,992

147,587

4,446,112





REFERENCE CONFIGURATION

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ITEM WEIGHT (18)	RCS SUBSYSTEM PRIMARY THRUSTERS VERNIER THRUSTERS MISC. MAIN FEED SUBSYSTEM AUXILIARY SUBSYSTEM 4,934	POWER APU (HYDRAULIC) 1,225 FUEL CELLS (2) FUEL CELLS TANKS (2) CABLING BLACK BOXES MISC. AVIONICS BLACK BOXES AVIONICS CABLING AVIONICS 1,425 ANTENNAS (4) CABLING 2,071
WEIGHT (LB)	3,496 3,519 5,295 4,276	(6,706) 3,485 3,221 (4,845) 1,320 1,275 598 558 558 (20,976)
ITEM	STRUCTURE THRUST STRUCTURE BODY (SHELL) WING TPS INTERNAL STRUCTURE	LANDING AND RECOVERY PARACHUTES LANDING GEAR/LEGS (4) PROPIJLSION RETRO ROCKET MOTOR HELIUM TANKS (MPS) OMS SUBSYSTEM ENGINES (2) HELIUM TANKS (2) HELIUM TANKS (2) REPOPELLANT TANKS (4) MISC.

P/A MODULE WEIGHT SUMMARY

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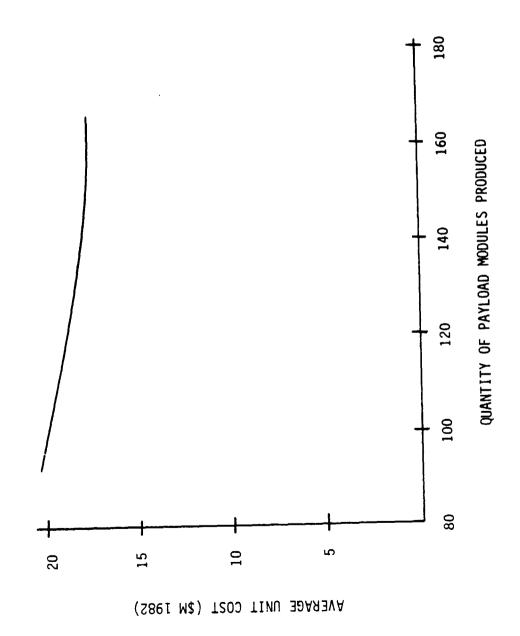
Ron

1091.8

TOTAL ACQUISITION COST 178.6 324.3 0.590 320.6 416.1 63.5 36.5 95.4 79.7 ESTIMATED COSTS (\$M 1982) PRODUCTION COST (3 UNITS) 49.0 164.6 113.9 429.0 171.4 19.3 36.3 45.2 251.6 236.0 149.2 129.5 210.4 27.2 34.5 10.5 76.1 WBS IDENTIFICATION GUIDANCE & NAVIGATION PROPULSION SYSTEMS POWER DISTRIBUTION **AUXILIARY SYSTEMS** POWER GENERATION INTEG/ASSY/TEST DATA MANAGEMENT STRUCTURES THERMAL SSME .3.1.10 1.3.1.11 1.3.1.5 1.3.1.6 1.3.1.8 1.3.1.2 1.3.1.3 1.3.1.4 1.3.1.7 .3.1.9 1.3.1.1

PROPULSION/AVIONICS MODULE HARDWARE COSTS





SOFTWARE ACQUISITION COSTS

WBS #	WBS IDENTIFICATION	EST. # OF MACHINE INST.	PESIGN CODE	NEW CODE	DDT & E COST (\$M 1982)
1.3.2.1	P/A MODULE AVIONICS S/W	60,400	6.0	1.0	45.789
1.3.2.2	P/A ENGINE CONTROL S/W	12,500	0.1	0.1	2.369
1.6.2.1	KSC LAUNCH PROCESSING SYSTEM S/W	1,710,000	0.25	0.5	119.911
1.7.2.1	VAFB LAUNCH S/W	1,710,600	90.0	0.1	5.552
1.8.1.1	MISSION CONTROL S/W	2,695,000	0.1	0.2	25.399
1.8.2.1	FLIGHT PLANNING	910,000	0.5	1.0	113.108





P/A MODULE SOFTWARE TRADE RESULTS

(SOFTWARE DDT & E COST)

MODIFIED ORBITER SOFTWARE

NEW SOFTWARE, NEW MACHINE

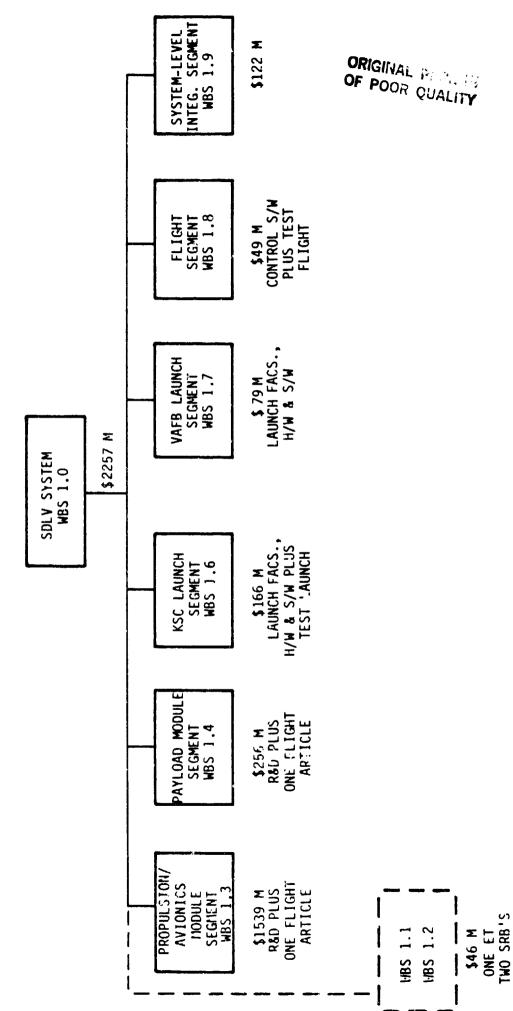
ORBITER S/W CONTRACTOR

\$ 24.80M

NEW CONTRACTOR

\$ 43.65M

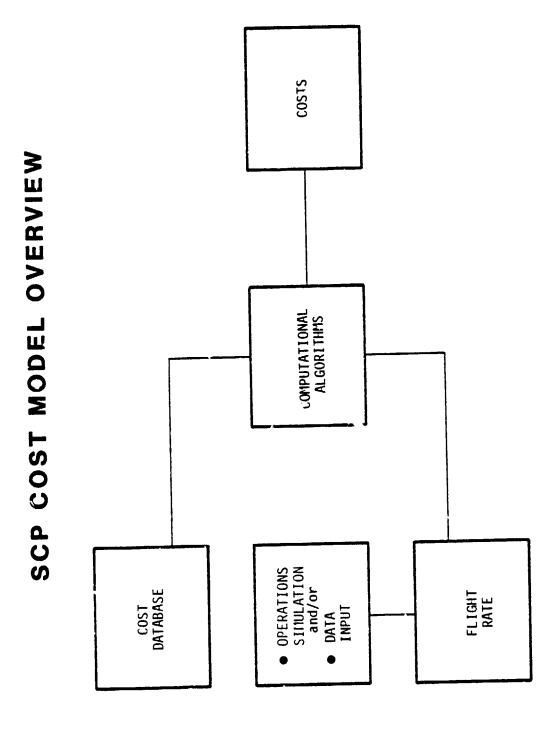
\$ 45.79M



ESTIMATE

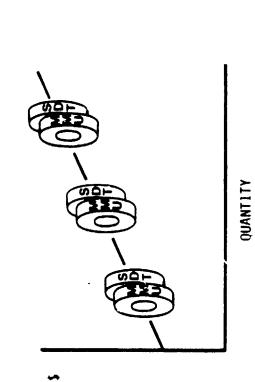
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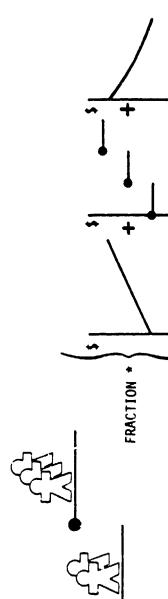
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ALGORITHM 4

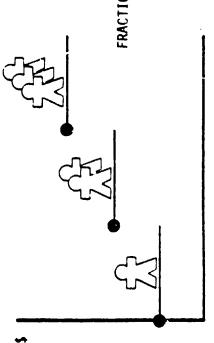
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ALGORITHM 3

ALGORITHM 1



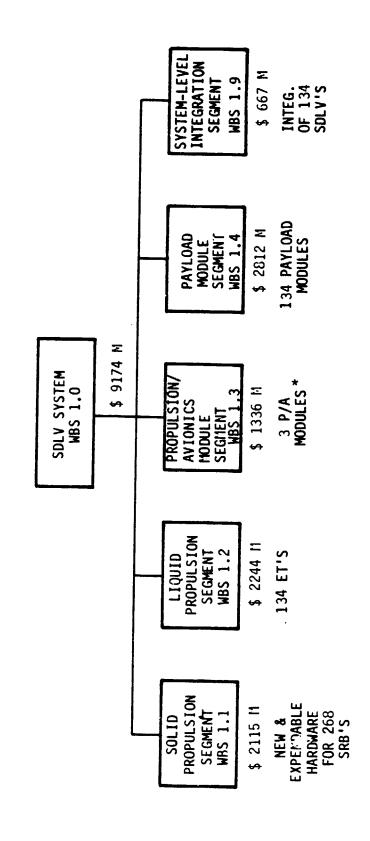
ALGORITHM 2 QUANTITY

DISPOSITION OF SCP-GENERATED COSTS IN SDLV ESTIMATES

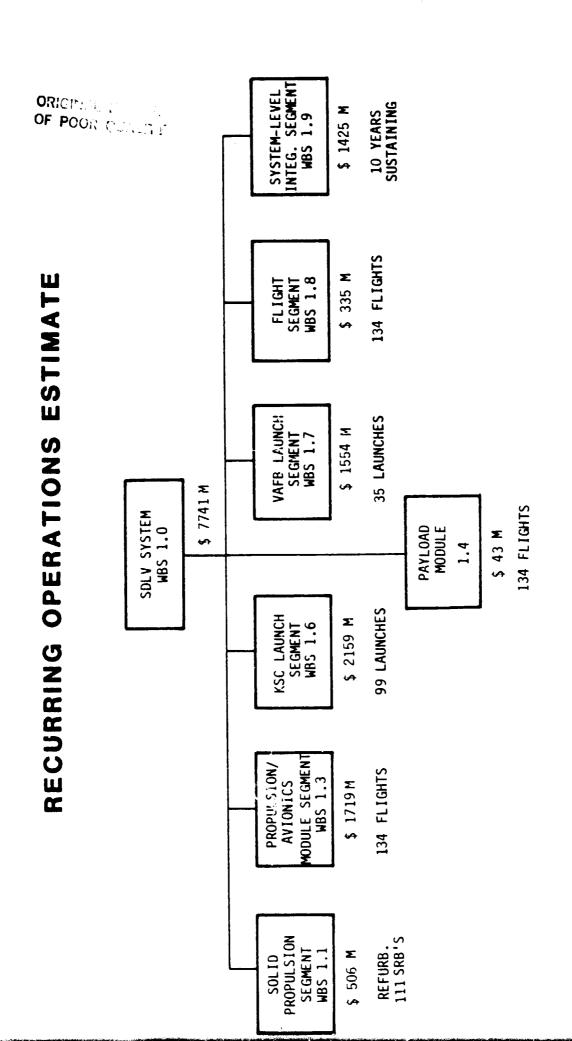
		APPL	APPLICABILITY TO SOLY	SOLV	CACTE CLABOTA DETINES CTC	2
COST NUMBER	COST CATEGORY	DIRECTLY	USED FOR	APPL ICABLE	AND SOLY TRANSPORTATION SYSTEMS	185 RD.
=	ORBITER SPARES		×			1.3.4
£2	ORBITER RECURRING SUPPORT		×			1.3.3.1
E3	FIELD SUPPORT, JSC			×		
.	REPLACEMENT GFE			×		
£3	FLIGHT DESIGN, PHASE 1		×			1.8.2.1
E6	FLIGHT DESIGN, PHASE 2	×			AVERAGE COST/FLIGHT	1.8.2.1
13	MCC OPERATIONS	×			PRORATA ANNUAL COST	1.8.3.1
£8	ORBITER FLIGHT SOFTWARE	×			PRORATA ANNEAL COST	1.3.2.1
£3	SIMULATOR OPERATIONS			×		
£10	CREM OPERATIONS			×		
111	ENGINEERING SUPPORT		*			1.3.3.1
£12	ORBITER ANALYTICAL INTEGRATION, RECURRING	×			AVERAGE COST/FLIGHT	1.4.2.2
£13	ORBITER ANALYTICAL INTEGRATION, SUPPORT	×			PRORATA AMBUAL COST	1.4.2.2
£14	NOT ASSIGNED					
E15	PROGRAM MANAGEMENT, JSC	×			PRORATA ANNUAL COST	1.6.3.1
E16	PROGRAM SUPPORT, JSC	×		OF OF	PRORATA ANNUAL COST	1.9.3.2
113	DIRECT CIVIL SERVICE & RELATED COSTS, JSC	×			PRORATA AMNUAL COST	1.9.3.2
E18	INDIRECT CIVIL SERVICE & RELATED COSTS, JSC	×		183. PO(PRORATA ANNUAL COST	1.9.3.2
613	PROPELLANTS, KSC	×		AL I	AVERAGE COST/FLIGHT PLUS PRORATA ANIMAL COST	1.6.4.1
£20	GSE SPARES, KSC	×		ԴՀ AU Ç	PRORATA AMMUAL COST	1.6.5.3
				a IV LITY		







*ABOVE AN BEYOND REFURBISHED P/A MODULE FROM DDT&E PROGRAM





MISSION OPTIONS

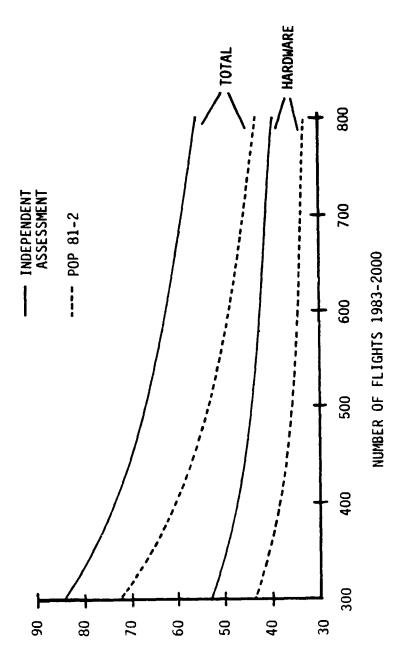
	NUMBER OF FLIGHTS THROUGH YEAR 2000	TS THROUG	H YEAR 2	000
	ALL FLIGHTS ON SHUTTLE	SHUT	SHUTTLE/SDLV MIX	×
	SHUTTLE	SHUTTLE	SDLV	TOTAL
LOW ACTIVITY	378	213	92	305
MODERATE ACTIVITY	675	267	134	501
HIGH ACTIVITY	801	462	167	629



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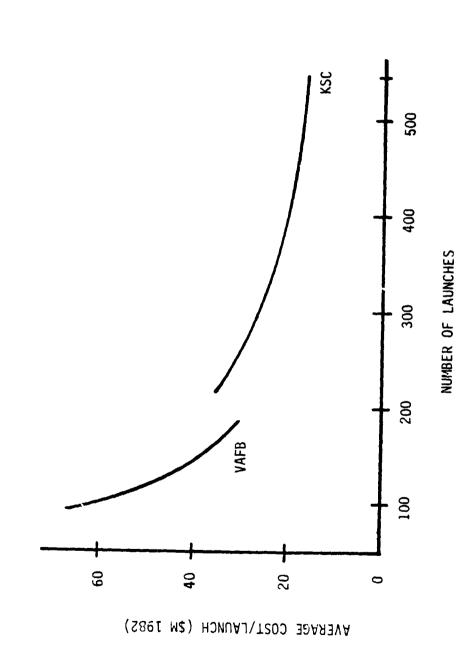
HARDWARE PLUS OTHER (NON-LAUNCH) SERVICES

COST/FLIGHT SENSITIVITY TO SHUTTLE FLIGHT RATE



AVERAGE COST/FLIGHT 1983-2000 (\$ 1982)





80

RECURRING TRANSPORTATION COSTS

FOR STS ONLY CASE

(\$ M 1982)

		LOW ACTIVITY	>	MOD	MODERATE ACTIVITY	/ITY	Ξ	HIGH ACTIVITY	
	FLTS	AVG CPF	COST	FLTS	AVG CPF	C0ST	FLTS	AVG CPF	C05T
HARDWARE	378	48.5	18,333	675	41.6	28,080	801	39.9	31,960
OTHER SERVICES	378	24.6	6,299	675	15.2	10,260	801	13.3	10,653
KSC LAUNCH	292	27.5	8,030	543	16.3	6,851	617	15.5	9,564
VAFB LAUNCH	98	57.8	4,970	132	40.5	5,346	184	32.5	2,980
			40,632			50,537			58,157

RECURRING TRANSPORTATION COSTS

FOR SDLV/STS MIX

(\$ M 1982)

		LOW ACTIVITY		MOD	MODERATE ACTIVITY	/1TY	Ξ	HIGH ACTIVITY	۷_
ELEMENT	FLTS	AVG CPF	1500	FLTS	AVG CPF	<u>COST</u>	FLTS	AVG CPF	C051
SDLV & COMMON COSTS									
1.1 SRB	305	22.2	6,771	501	19.4	9,719	629	19.0	11,951
1.2 ET	305	19.1	5,825	501	16.7	8,368	629	16.1	10,127
1.3 P/A MODULE	95	12.8	1,178	134	12.8	1,715	167	12.8	2,138
1.4 P/L MODULE	95	23.6	2,171	134	21.3	2,854	167	20.2	3,373
1.6 KSC LAUNCH	235	33.6	7,896	386	21.8	8,414	484	18.0	8,712
1.7 VAFB LAUNCH	70	70.2	4,914	115	44.4	5,106	145	37.6	5,452
1.8 SOLV FLIGHT OPS.	95	3.1	285	134	2.5	335	167	2.3	384
1.9 SYS. INTEG.	305	17.7	5,398	501	10.6	5,311	629	8.6	6,164
STS UNIQUE COSTS									
ORBITER HARDWARE	213	7.9	1,683	367	9.9	2,422	462	0.9	2,772
ORBITER FLIGHT OPS.	213	11.8	2,513	367	6.6	3,633	462	9.2	4,250
			38,634			47,877			55,323

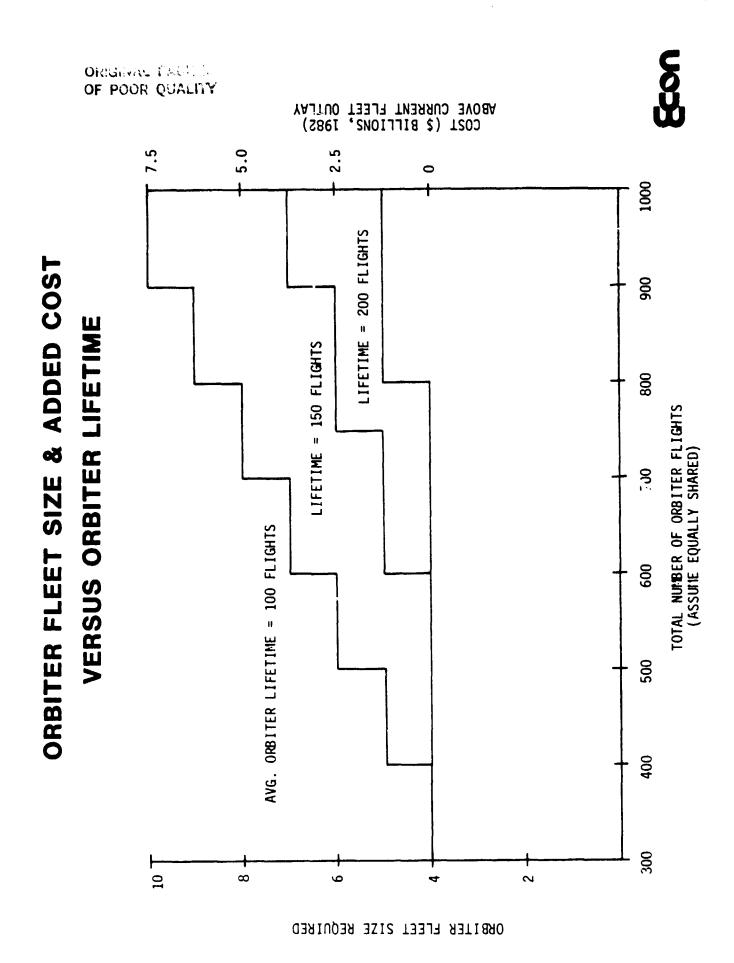


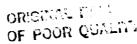
COST COMPARISON AT EQUAL TRANSPORTATION CAPABILITY

(M 1982 \$)

		1 ₹ 0 1	LOW ACTIVITY	MODERAT	MODERATE ACTIVITY	нІСН	HIGH ACTIVITY
		STS	SDLV/STS	STS	SDLV/STS	STS	SDLV/STS
ACQUISITION COSTS							
DDT & E		N/A	2,257	N/A	2,257	N/A	2,257
PRODUCTION (P/A FLEET PLUS SOLV INTEGRATION)	>.	N/A	2,002	N/A	2,002	N/A	2,002
SUBTOTAL			4,259		4,259		4,259
DIFFERENCE		4-	-4,259	-4,	-4,259	4-	-4,259
RECURRING COSTS		40,632	38,634	50,537	47,877	58,157	55,323
DIFFERENCE	C;	Ŧ	+1,998	+2,	+2,660	¥ 	+2,834
E POO!	rico :	40,632	42,893	50,537	52,136	58,157	59,582
DIFFERENCE	QUALI	-5	-2,261	Ţ	-1,599	1	-1,425
	[°.' `~ ∀					J	







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STUDY FINDINGS

SDLV SYSTEM CAN BE ACQUIRED FOR ABOUT \$4.3 BILLION (1982):

DEVELOPMENT PLUS ONE FLIGHT ARTICLE = \$2.3 BILLION

PRODUCTION OF THREE ADDITIONAL P/A MODULES = \$2.0 BIILION

THESE ESTIMATES ASSUME:

EXTENSIVE USE OF EXISTING SHUTTLE HARLWARE & SOFTWARE

USE OF SHUTTLE FACILITIES ON NON-INTERFERENCE BASIS

COMPARISON OF STS WITH SDLV/STS MIX AT EQUAL TRANSPORTATION CAPABILITY SHOWS:

RECURRING COST SAVINGS FAVOR SDLV (\$2.0 B TO \$2.8 B DEPENDING ON MISSION MODEL)

ACQUISITION (NONRECURRING) COST SAVINGS FAVOR STS BY \$4.3 BILLION

OVERALL LIFE CYCLE COST SAVINGS FAVOR STS BY \$2.3 TO \$1.4 BILLION

HOWEVER, SDLV IS A GOOD INVESTMENT IF:

UNIQUE SDLV MISSION PERFORMANCE ALLOWS SDLV ACQUISITION COSTS TO BE SUNK, OR SHUTTLE FOLLOW-ON PROCUREMENT CAN BE REDUCED BY MORE THAN ONE ORBITER

